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Evaluation of a Pneumatic Guy-Line Deicing Boot

John W. Govoni and Charles H. Franklin

February 1992

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PREFACE

This report was prepared by John W. Govoni, Physical Science Technician, Snow and Ice Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory, and Charles H. Franklin of the Franklin Engineering Company. Funding was provided by DA Project 4A762784AT42, Task SS, Work Unit 002, *Mechanical Design for Icing Environments.*

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Evaluation of a Pneumatic Guy-Line Deicing Boot

JOHN W. GOVONI AND CHARLES H. FRANKLIN

INTRODUCTION

Concern about the damage inflicted by atmospheric icing has grown, particularly damage to the increasing number of transmitting towers in the northern United States (Mulherin 1986). Transmitting towers, as well as other structures, are frequently located at the summits of mountains or other high elevation areas where atmospheric icing is most severe. In the past, these structures have sometimes collapsed because of guy-line failure from extreme ice loads. Stimulated by the desire to alleviate this problem, the Franklin Engineering Company developed two pneumatic guy-line deicing boots. Both were tested on the summit of Mt. Washington, New Hampshire, a location well known for its extreme icing events. This report discusses the results of these tests, which were made during the winter months of 1986–1988.

METHODOLOGY

In 1986 a 3-m-long pneumatic boot, designed to shed ice by periodically expanding, was tested at the facilities of the Mt. Washington Observatory. The boot (Fig. 1) was constructed so that it could be easily installed by simply slipping it over a 1-cm-diameter multistrand steel cable (similar to those used to support transmission towers). This prototype boot was attached to the steel cable at each end with hose clamps and silicone sealant (Fig. 2). The boot was operated by a regulated high-pressure nitrogen gas tank that was located about 10 m from the experiment site. The advantage of using nitrogen is that it maintains sufficient pressure at low temperatures. Battery-powered timers mounted in an enclosure were used to control inflation time and the interval between boot inflations (cycle frequency). The cycle frequency and inflation time could be changed by manually setting these timers. Frequent observations of this prototype cable boot during the 1986–87 icing season showed that it performed extremely well; there were no uncontrollable ice formations on the boot.

Because of the favorable results from the pilot study, a 14-m cable boot, designed to encase an entire guy wire, was developed for the 1987–88 icing season. This longer boot was assembled on a 1-cm steel cable that was used as one of the guy lines on a 9.5-m-high tower. The steel tower, along with an instrument shelter, was located on the helicopter pad near the summit of Mt. Washington. The tower was a component of another CRREL study designed to measure the ice and wind loads on the structure (Fig. 3).

Regulated high-pressure dry nitrogen gas was again used to inflate this boot, which required less than 3.3 mm^3 of gas at 172-kPa pressure per inflation cycle. With a standard tank (9.3 m^3) of nitrogen, the boot will operate during an entire icing season. The electrical timers as well as the gas regulators were all housed in the instrument shelter located less than 15 m from the tower.

During this time, Franklin Engineering was also evaluating the performance of a pneumatically deiced ice detector installed at the same location. We decided to trigger boot inflations with a signal from the ice detector. The Franklin ice detector, which cycled when 90 g of ice collected on its surface, was mounted on the roof of the instrument shelter, close to the tower (Fig. 4). It was wired directly to the boot cycling controls inside the instrument shelter and activated the main power switch for the boot when ice was detected (Franklin and Rogne 1990). The idea here was to assess the performance of the boot when it was controlled by the ice detector because the gas supply could be conserved with the cycle frequency being controlled by the severity of the icing conditions. As explained later, this cable boot also worked well during the 1987–88 season.

RESULTS AND DISCUSSION

Table 1 contains a summary of all data acquired from the pneumatic boots during icing events of the 1986–88 seasons. Cycle frequency and inflation time are the time between inflations of the boot and the duration of the

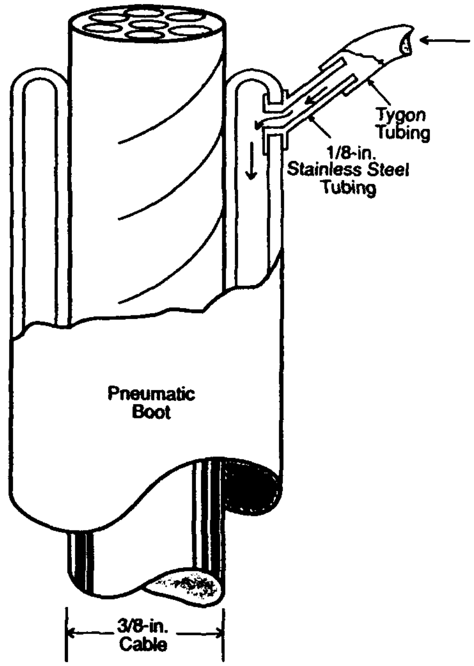


Figure 1. Cut away drawing of boot encasing the guy wire (1 in. = 25.4 mm).

inflation period respectively. The amount of ice on the boot during these tests was manually measured, as was the amount of ice on an unbooted 1-cm control cable located next to the boot. Liquid Water Contents (LWC) as well as mean water Droplet diameters (Dd) were obtained from rotating multi-cylinder measurement devices, a standard measurement made by the Observatory whenever the summit is in the clouds and icing is evident. Ice types as described in the table are subjective descriptions of the type of ice that was forming during a boot deicing run. Soft rime ice is usually found in cold and windy conditions, usually has a density of 0.1 to 0.3 g/cm^3 and is very fragile. Rime and hard rime are found during higher temperatures (–12 to –7°C) and have a density range of 0.3 to 0.6 g/cm^3. This ice type has considerably higher adhesion strength than soft rime. When the air temperature is near the freezing point and much liquid water is present (sometimes freezing rain), milky rime ice and glaze ice form. This type of ice, with densities ranging from 0.6 to 0.9 g/cm^3, causes very large loads and can be particularly damaging because it accumulates rapidly.

As an aside, we have plotted the ice accumulated on the control cable versus the measured LWC from the data in Table 1 in Figure 5. The points have also been labeled according to the type of ice formation. Unfortunately, the LWC can not be measured during the glaze events because of excessive moisture during these warm conditions. This figure shows a general relationship between the ice accretion and the LWC. With the one exception of the 30.5-cm rime case, the accretion amount generally increases with the liquid water content. There is considerable scatter shown owing to other factors involved, such as the temperature, wind speed, droplet

Figure 2. Prototype cable boot located on the roof of the Mt. Washington Observatory during the 1986–87 icing season.

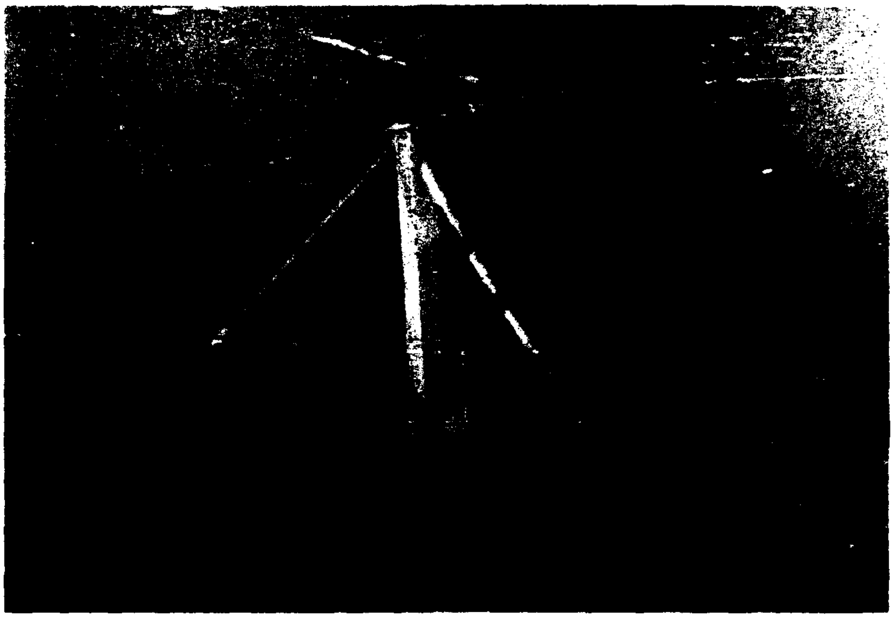


Figure 3. Guyed tower along with the instrument shelter located on the helicopter pad. Note the ice-free booted guy line.

size and length of accretion period. It is also apparent that most soft rime and rime accumulations are generally small, occurring at low values of LWC, while the milky and hard rime form large accumulations in clouds having a high LWC. This figure makes clear that the boots were evaluated under a large range of icing conditions.

Over the two icing seasons several combinations of cycle frequencies and inflation times were tested, as shown in Table 1, ranging from cycle frequencies of every 9 to 60 minutes and inflation times of 15 to 30 seconds. With these various combinations, the table indicates that most of the time the boot was clear or had a spotty covering of ice (less than 0.15 cm at a few

Figure 4. Franklin ice detector mounted on the roof of the instrument shelter.

Table 1. Summary of data taken on the two pneumatic deicing boots during the two icing seasons of 1986–1988.

Date	*Cycle frequency (min)*	*Inflation time (s)*	*Ice on boot (cm)*	*Ice on control cable (cm)*	*LWC (g/m^3)*	*Dd (μm)*	*Ice type*
			3-m boot				
6 Mar 87	15	15	Clear	10.2	—	—	soft rime
7 Mar 87	15	15	Clear	15.2–20.3	0.42	9	soft rime
16 Mar 87	45	15	Spotty	0.6–1.9	0.10	10	soft rime
16 Mar 87	45	15	Spotty	0.6–1.9	0.12	10	soft rime
17 Mar 87	45	15	Clear	0.6–1.9	0.14	11	soft rime
18 Mar 87	45	15	2.5	2.5–5.0	0.20	7	rime
19 Mar 87	45	15	Spotty	5.0–7.6	0.29	10	rime
20 Mar 87	45	15	Spotty	12.7	—	—	rime
21 Mar 87	45	15	Spotty	2.5–5.0	0.12	25	rime
22 Mar 87	15	15	Spotty	12.7	0.77	27	hard rime
22 Mar 87	15	15	Clear	12.7	—	—	glaze
23 Mar 87	15	15	0.6	0.6	0.35	19	soft rime
26 Mar 87	15	15	Clear	2.5–5.0	0.44	13	rime
27 Mar 87	9	30	Clear	15.26	0.43	14	rime
30 Mar 87	60	30	0.3	0.3	—	—	glaze
1 Apr 87	60	30	1.3	1.3	—	—	rime
1 Apr 87	15	15	Manually deiced		—	—	rime
3 Apr 87	15	15	Clear	2.5	—	—	rime
4 Apr 87	15	15	Clear	15.2–17.8	—	—	rime
			14-m boot (not controlled by ice detector)				
13 Dec 87	15	15	Clear	5.0	0.48	16	milky rime
14 Dec 87	15	15	Clear	20.3–25.4	0.77	17	hard rime
15 Dec 87	15	15	Clear	30.5	0.12	14	rime
16 Dec 87	15	15	Clear	5.0–10.2	0.2	11	rime
19 Dec 87	15	15	0.6	5.0–10.2	0.36	12	hard rime
20 Dec 87	15	15	0.1	1.3–2.5	0.21	9	milky rime
21 Dec 87	15	15	Clear	10.2–15.2	0.62	14	milky rime
21 Dec 87	15	15	Clear	10.2–15.2	0.52	12	hard rime
1 Mar 88	15	15	Clear	7.6	—	—	hard rime
3 Mar 88	15	15	0.1	6.3	0.48	10	hard rime
3 Mar 88	15	15	Clear	6.3	—	—	hard rime
4 Mar 88	15	15	Clear	2.5	—	—	milky rime
4 Mar 88	15	15	Clear	2.5–7.6	0.64	15	milky rime
8 Apr 88	15	15	0.1	7.6	—	—	glaze

locations). Our observations determined that an inflation cycling frequency of 15 minutes for a duration of 15 seconds could keep the boot free of ice under the most severe icing conditions. This is evident from the data in Table 1 for the events recorded during March of 1987. During this month, the boot experienced four different ice types ranging from soft rime to glaze. Once the cycle frequency was set for every 15 minutes with an inflation time of 15 seconds, it completely shed itself of all ice as seen from the data recorded after 3 April 1987.

We observed throughout both icing seasons that, during light winds and cold conditions, when soft rime is forming, the boot did not shed ice very well, as evident from the information recorded on 23 March 1987. However, soft rime formations are generally small and very fragile, and seldom pose structural problems for guy lines.

The largest ice accretion measured on the control cable during the testing period was 30.5 cm, recorded after the 15 December 1987 rime ice storm. As Figure 6 shows, the unprotected guy line is heavily iced (foreground) while the booted guy line is ice free (background).

Figure 7 shows photographs taken of the booted guy line and the bare guy line on 8 April 1988 immediately following a glaze icing event. Again, the photographs show that the boot-protected guy line has negligible ice,

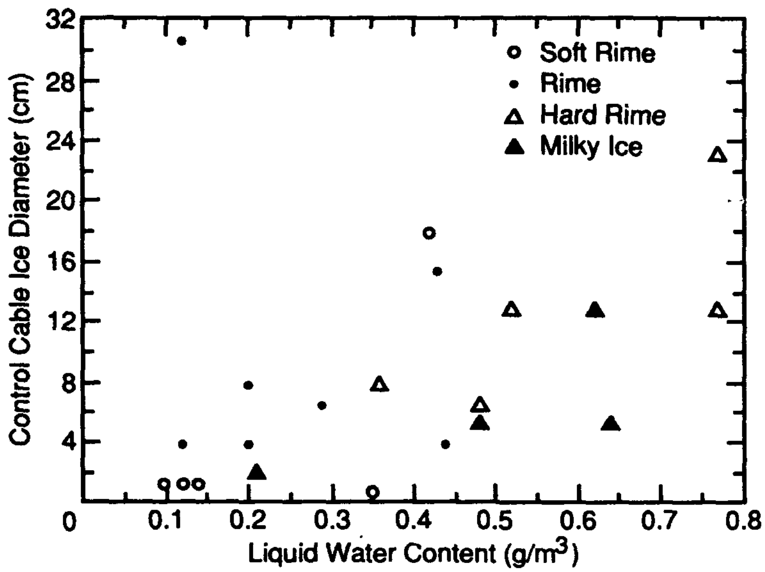
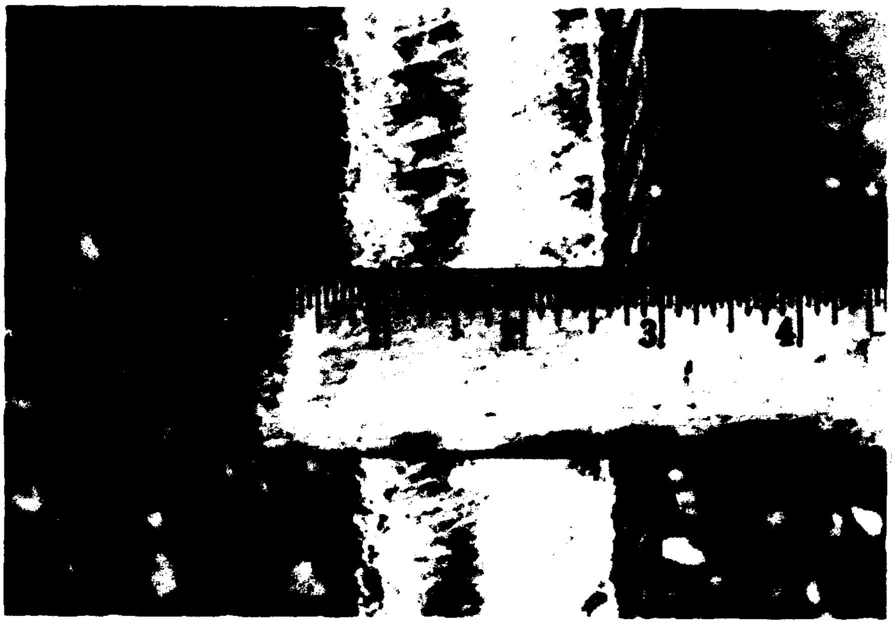
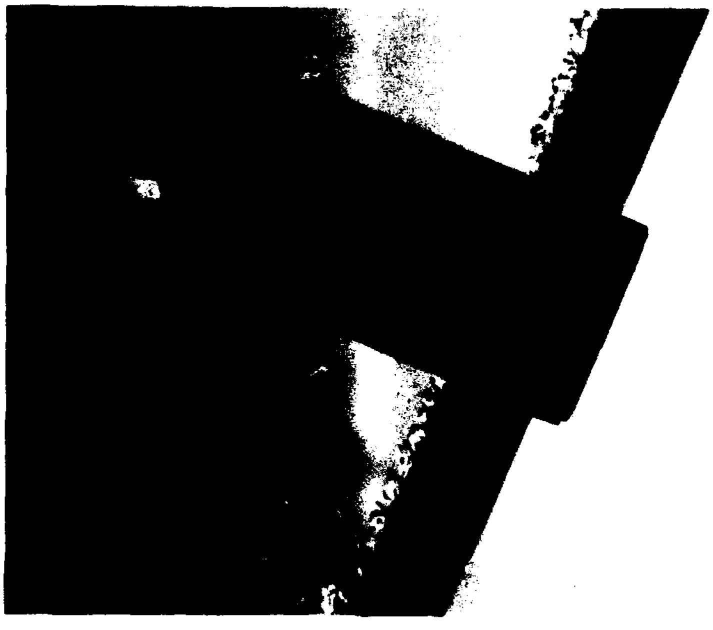


Figure 5. Ice accumulation on control cable versus the measured liquid water content from Table 1.

Figure 6. Largest atmospheric ice accretion (30.5 cm) measured on the unprotected guy line. Note the ice free booted guy line.



a. Unprotected line.



b. Protected line.

Figure 7. Comparison of ice accumulation between the protected and unprotected guy lines after an icing storm.

while the control cable has accumulated 7.6 cm of dense glaze ice.

We noticed that between inflation cycles, the boots seemed to shed ice, so we conducted a test to see if the boot could self-shed indefinitely without inflation. However, when left for several hours, small areas along the length of the boot acquired rings of ice about 2.5 to 5.0 cm in length. We then stopped the tests because too much ice was accumulating. After initiating the inflation cycles again, however, these rings were difficult to remove, often requiring two to three cycles to be completely shed. These observations were made during a period of moderate rime icing and may not reflect behavior under other types of icing.

CONCLUSIONS

During this icing study, we found that both prototype boots worked well and no sizeable ice accretions formed on the protected cables during their operation. They were able to easily shed ice during all conditions, even when we deliberately attempted to ice the booted cables. In addition, we found that both boots showed a tendency to self-shed ice between inflation cycles, apparently because the ice accretion caused the cable to twist, shearing off much of its accumulation.

As stated earlier, the 14-m long cable boot worked extremely well during the evaluation period and its performance did not degrade when the automatic timing cycles gave way to the ice detection cycles. Considerably less gas was used when the ice detector initiated inflation because the cycling frequency was being controlled by the severity of the icing conditions.

Owing to the simplicity of this boot system, in most cases it can be retrofitted to existing transmission lines and other structure support cables. We believe that the combination of the boot and ice detector will provide protection for cables in the locations prone to the most severe icing

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Mulherin, N.D. (1986) Atmospheric icing on communication masts in New England. USA Cold Regions Research and Engineering Laboratory, CRREL Report 86-17.

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During the two winter field seasons of 1986–88, a 3-m-long pneumatic cable deicing boot was tested and evaluated by CRREL at the summit of Mt. Washington, New Hampshire. Favorable results from this pilot study led to the development of a longer (14-m) pneumatic boot. This longer boot, which was used to entirely encase one of the guy lines supporting a 9-m-high tower, was evaluated at the summit of Mt. Washington during the 1987–88 icing season. The performance of both pneumatic cable deicing boots during a variety of icing conditions indicates that this simple, cost-effective method of ice prevention on guy wires may be suitable for practical application.

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